Plasma etching on large-area mono-, multi- and quasi-mono crystalline silicon

Davidsen, Rasmus Schmidt; Schmidt, Michael Stenbæk; Boisen, Anja; Hansen, Ole

Publication date:
2013

Document Version
Peer reviewed version

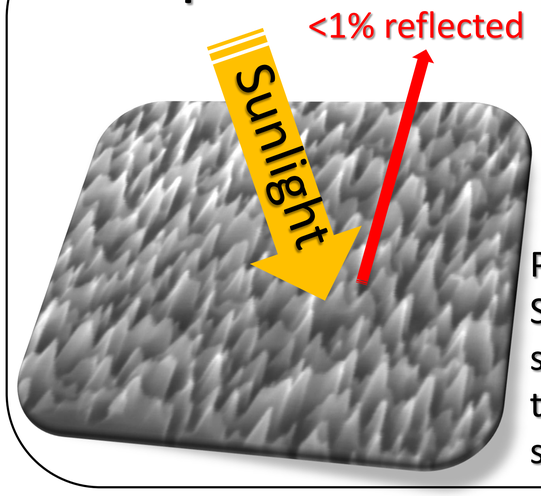
Plasma etching on large-area mono-, multi- and quasi-mono crystalline silicon

Rasmus Schmidt Davidsen*, [1], Michael Stenbæk Schmidt[1], Anja Boisen[1], Ole Hansen[1]

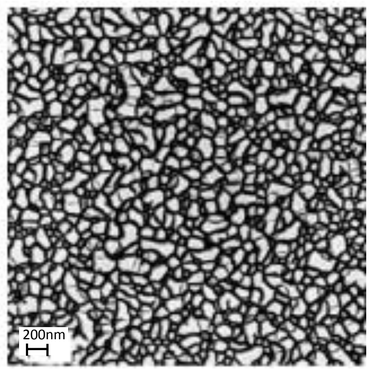
[1] Department of Micro- and Nanotechnology, Technical University of Denmark (DTU), 2800-Lyngby, Denmark

*rasda@nanotech.dtu.dk, Ørsteds Plads building 345East, 2800 Lyngby, Denmark

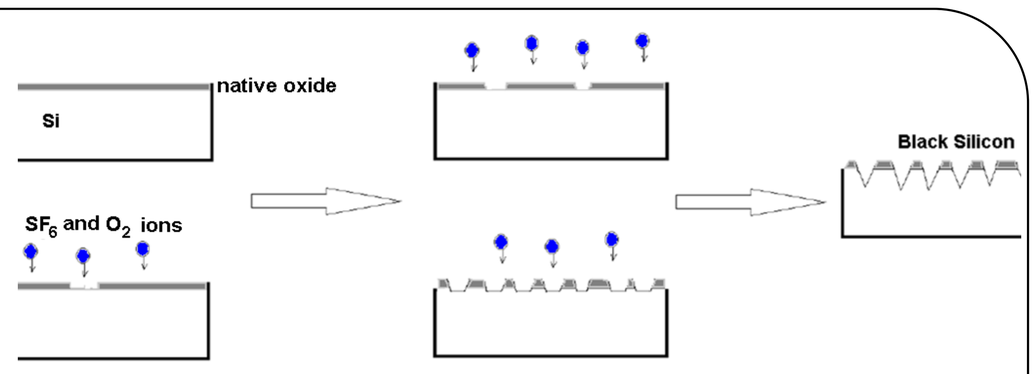
Concept



Plasma-etched "Black Silicon" nanostructures significantly reduce the reflectance of sunlight

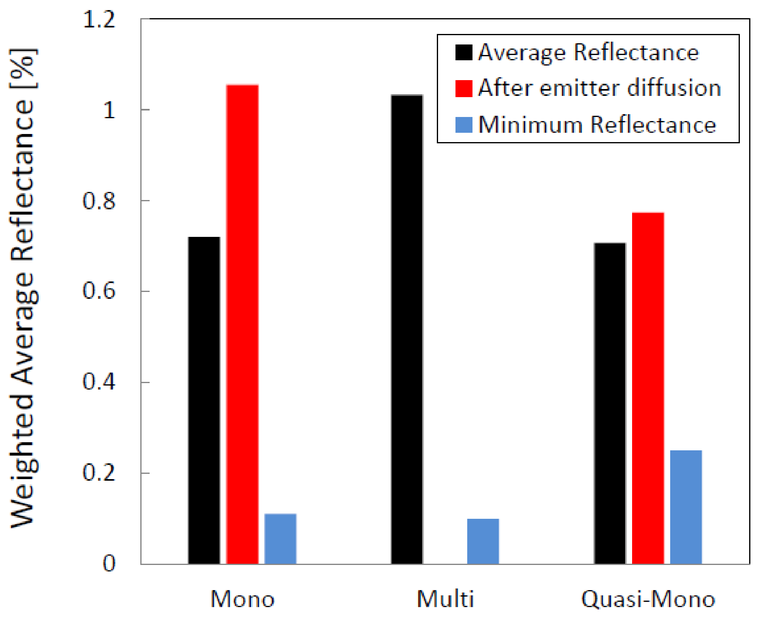


SEM-image (top-view) of the RIE-textured, nanostructured Si surface.



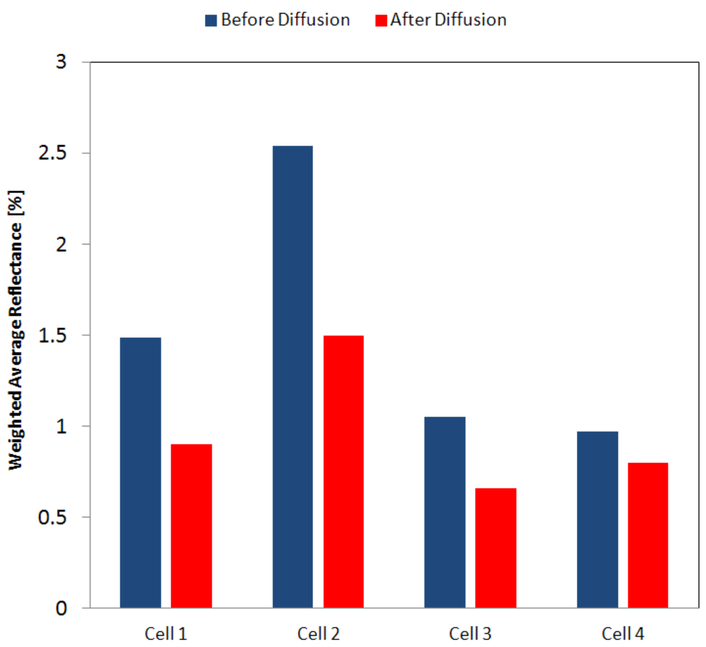
The nanostructures are fabricated by reactive ion etching, in which SF_6 and O_2 ions etch and auto-passivate the surface simultaneously. This creates a maskless etching of nanostructures at appropriate process conditions.

Below 1% reflectance for different industrial types of Si:



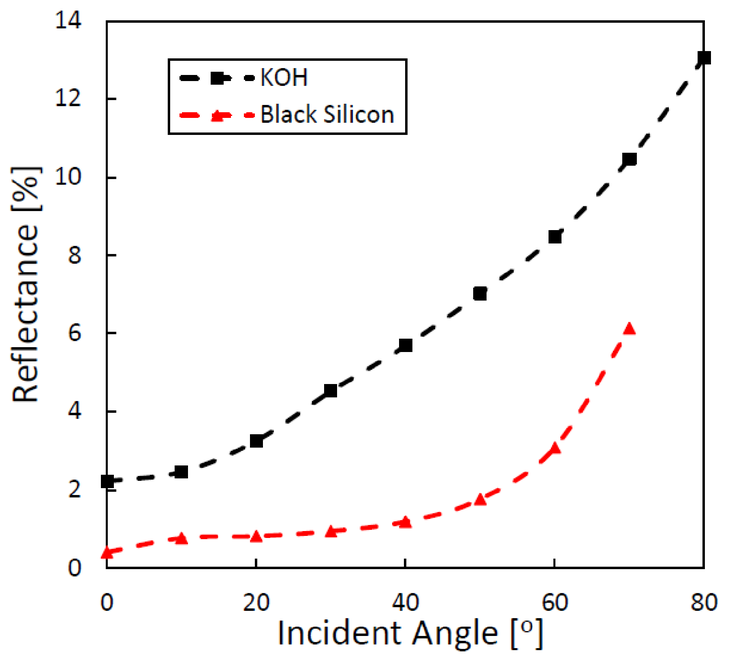
Weighted (AM1.5) average reflectance before and after emitter diffusion as well as the minimum reflectance of mono-, multi- and quasi-mono Si surfaces, respectively.

$POCl_3$ Emitter Diffusion



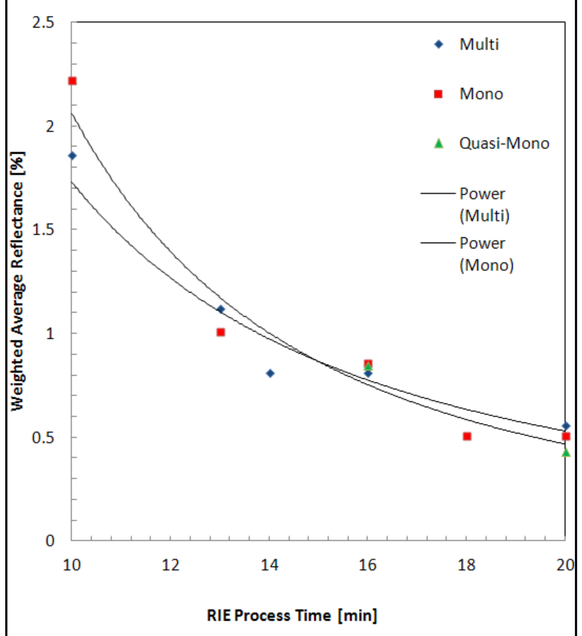
Weighted (AM1.5) average reflectance before and after emitter diffusion (150 Ω/sq.) for mono-crystalline Si with slightly different nanostructure texturing.

Varying incident angle



Weighted average reflectance as function of incident angle for a KOH-textured (squares) and RIE-textured (triangles) mono-c r Si substrates.

Etching time



Reflectance as function of RIE process time for mono-, multi- and quasi-mono crystalline Si, respectively. All other parameters than time were fixed. The general trend suggests that the reflectance decreases with t^{-2}.

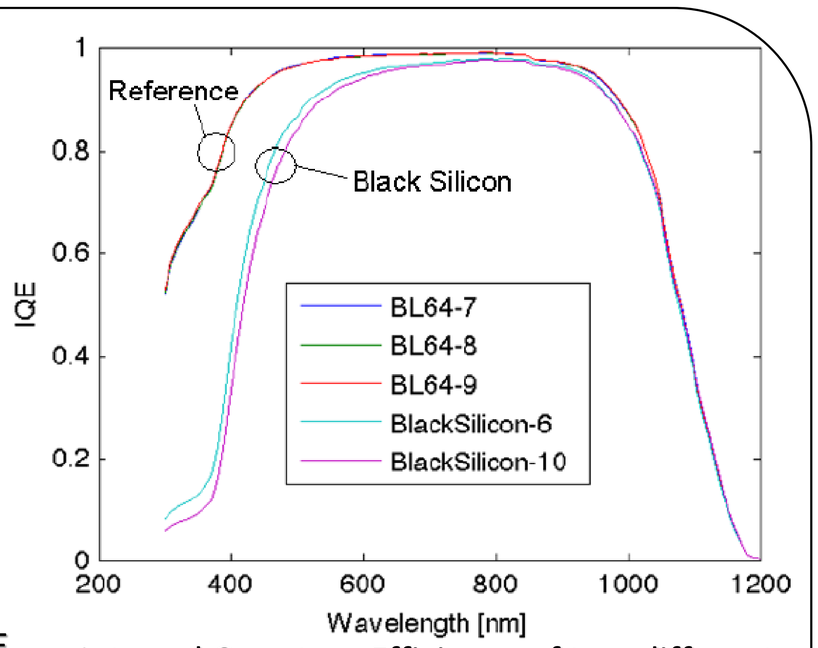
Electrical Results:

	Total Carrier Loss	Emitter recombination
KOH	1.385 mA/cm^2	0.761 mA/cm^2
RIE	4.163 mA/cm^2	3.322 mA/cm^2

Calculated total carrier loss and carrier loss due to emitter recombination for the KOH- and RIE-textured cell.

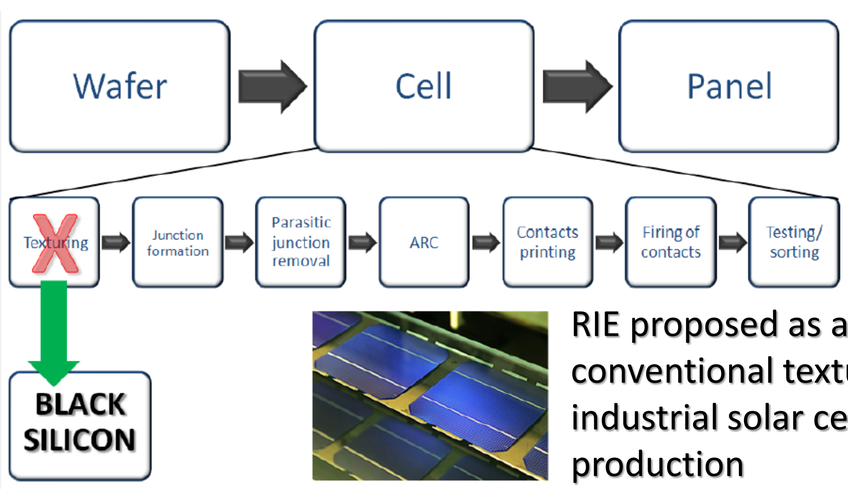
	PCE [%]	J_{SC} [mA/cm^2]	V_{OC} [V]	FF	R_{av} [%]
KOH	17.6	36.8	0.62	77.8	2-3
RIE, type 1	15.7	35.3	0.61	72.8	2.85
RIE, type 2	16.5	35.2	0.61	77.7	2.20

PV performance results including power conversion efficiency, PCE, short-circuit current, J_{SC}, open-circuit voltage, V_{OC}, fill factor, FF and weighted average reflectance after emitter diffusion, R_{av}, of the RIE- and KOH-textured cells.



Internal Quantum Efficiency of two different black Si cells and three KOH-textured reference cells. Loss in short-wavelength IQE indicates surface recombination.

Proposed Industrial Application:



RIE proposed as alternative to conventional texturing step in industrial solar cell production

Rasmus Davidsen,
PhD-student, DTU Nanotech
M.Sc., Nanotechnology Engineering
Technical University of Denmark (DTU)
rasda@nanotech.dtu.dk
+45 26187249

DTU Nanotech
Department of Micro- and Nanotechnology